"Physics of Auroral Phenomena", Proc. XXVIII Annual Seminar, Apatity, pp. 78-81 , 2005

Polar Geophysical Institute

LONG-TERM BEHAVIOUR OF THE MAGNETOTAIL STRETCHING

T.A. Yahnina[1], A.G. Yahnin[1], D.A. Yahnin[2], P.T. Newell[3], and T. Sotirelis[3]

[1]*Polar Geophysical Institute, Apatity, Russia*
[2]*Faculty of Physics, St-Petersburg State University, St-Petersburg, Russia*
[3]*Applied Physics Laboratory, Johns Hopkins University, Laurel, Maryland, USA*

Abstract. It is known that the stretching of magnetic field lines in the near-Earth magnetotail is characterised by the latitude of isotropy boundary (IB) of energetic protons. In the DMSP satellite particle data, the IB is represented by a specific boundary called b2i. We use b2i values obtained in 1984-2004 for investigation of the long-term evolution of magnetotail stretching. We show that during two solar cycles the annual average of b2i latitude has a pronounced variation, which is likely governed by interplanetary parameters. Two distinct minima (in March and October) are clearly seen in the annual behaviour of b2i. It means the magnetosphere is more stretched in spring and autumn.

Introduction

Observations of low-altitude satellites measuring particles with different pitch angles exhibit a clear boundary between isotropic precipitation of energetic particles at higher latitudes and anisotropic fluxes (trapped population prevails over precipitating one) at lower latitudes. This boundary called "isotropy boundary" is interpreted (and this interpretation has been evidenced in numerous studies) as the ionospheric projection of the transition between regions of adiabatic motion of particles in the dipole-like magnetic filed and non-adiabatic motion in the equatorial current sheet region (Sergeev et al., 1983). This boundary is strongly affected by the intensity and location of the current sheet. The latter determines the stretching of the magnetic field in the near-Earth region. The lower latitude of IB, the more stretched is the magnetic field (as evidenced by geosynchronous observations). The best correlation is found for IB near midnight. Sergeev and Gvozdevsky (1995) introduced a special index for monitoring the near-Earth magnetotail configuration (MT-index). This index is a latitude in the midnight sector calculated from local measurements of IB of energetic (E=80-250 keV) protons using an empirical dependence of IB on MLT. The earlier studies of IB have been done with the data from low-orbiting NOAA satellites. An analogue of IB in data of DMSP satellites is so-called b2i - the latitude of the maximal flux of protons with energy E>3 keV (Newell et al., 1996). An example of the b2i determination from the DMSP satellite data is shown in Fig. 1. Newell et al (1998) have demonstrated that the MT-index based on b2i measurements also correlates well with the magnetotail stretching.

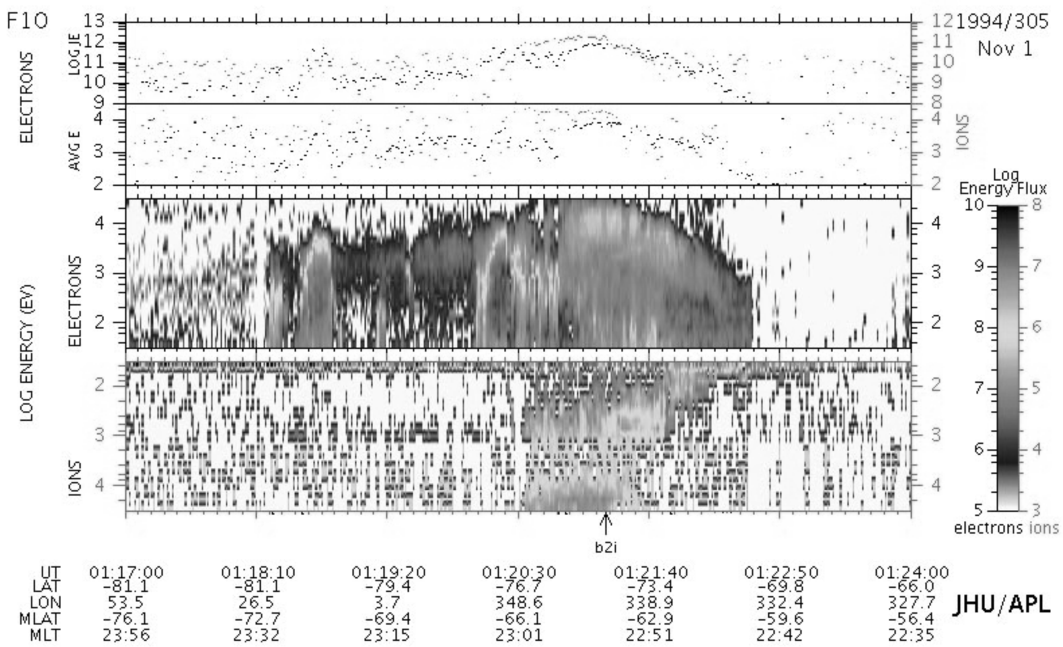

Fig. 1. Determination of b2i from DMSP particle data

The b2i latitude is routinely determined from the DMSP particle data by the Auroral Particles and Imagery Group at JHU/APL. The interval of continuous measurements covers more than 20 years. This allows us to investigate the long-term behaviour of the magnetotail stretching. Here, we report the preliminary results of such an investigation. Along with b2i, we used the OMNI database for 1984-2004 (hourly averaged interplanetary parameter data as well as sunspot numbers).

Observational results

Variations of b2i (magnetotail stretching) during two successive solar cycles

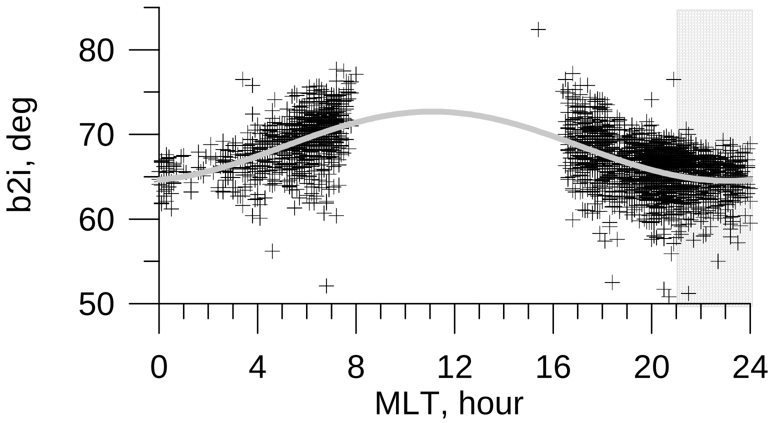

Fig. 2. Spatial distribution of b2i.

To investigate the long-term variations, we used the averaged individual b2i measurements from 21-24 MLT sector (analogue of the MT-index). (Determined in this way b2i values are well correlated with the averaged MT-index, not shown). From twenty one-year (1984-2004) data set, some 100000 individual determinations of b2i were used. Spatial distribution of individual b2i's obtained from the DMSP observations in 2000 is shown in Fig. 2. Every tenth sample is presented in the Figure. Shading marks the 21-24 MLT sector. The gap around noon is due to peculiarities of the DMSP satellite orbit.

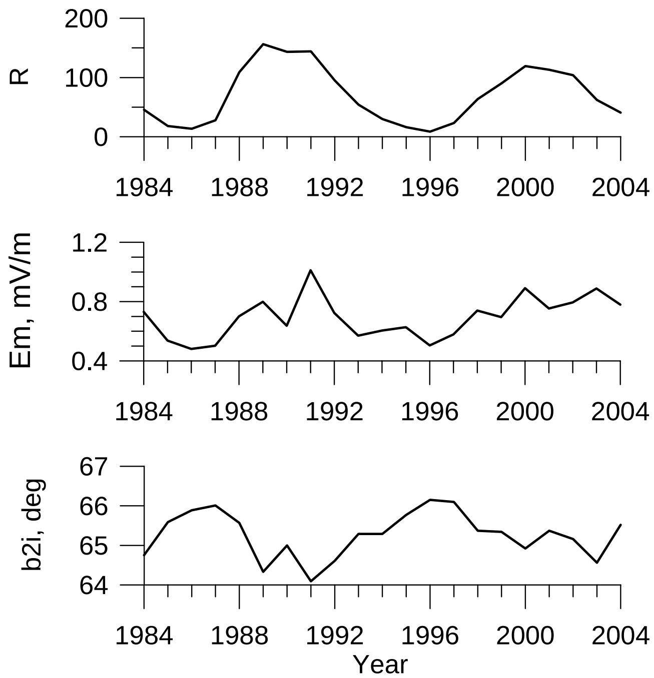

Fig. 3. Long-term variations of b2i, Em, R

The observations cover almost two solar cycles 22 and 23. During the two solar cycles, the annual average of b2i exhibits pronounced variations (Fig. 3, bottom). Upper panels show annual averages of sunspot number, R, and solar wind electric field $Em=V_{sw}*B*\sin^3\theta/2$ (V_{sw} is the solar wind velocity, B is $(Bz^2+By^2)^{1/2}$, θ is the cone angle). Note, that b2i is nicely anticorrelated with Em. Maximal b2i values (more dipole-like magnetosphere) are found in 1987 (near the minimum of solar cycle 22) and in 1996 (near the minimum of solar cycle 23). Minimal b2i value (more stretched magnetosphere) is found in 1991 near the maximum of solar cycle 22. But, in 2000 (maximum of cycle 23) the b2i minimum is not distinct. In contrast to the behaviour of b2i during the declining phase of the preceding cycle, a strong decrease of the latitude is observed in 2002-2003. However, such variations of b2i are in agreement with the variations of the interplanetary electric field (middle panel), which also demonstrate an "anomalous" behaviour in 2002-2003.

Seasonal dependence of b2i (magnetotail stretching)

Application of the superposed epoch analysis to the monthly averaged b2i values for 1984-2004 showed that the annual b2i variation has two distinct minima in March and October (Fig. 4). This means that the magnetotail is more stretched in equinoxes in comparison with other seasons. Note, that in average, the geomagnetic activity also demonstrates a pronounced seasonal dependence, being increased during equinox periods (Russell and McPherron, 1973).

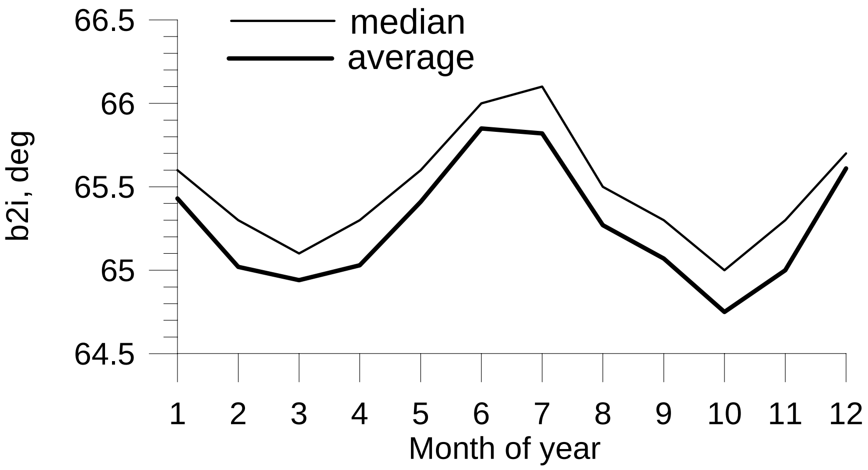

Fig. 4. The annual variation of monthly averaged and median b2i values

Results and discussion

On the basis of particle observations onboard low-orbiting satellites, we investigated the long-term behavior of the magnetotail stretching. We conclude that:

- The configuration of the magnetosphere varies pronouncedly during a solar cycle, namely, the near-Earth magnetosphere is more dipole-like in minimum, and it is more stretched in maximum of the cycle.
- The magnetosphere is more stretched in equinox in comparison with other seasons.

The stretched magnetic field in the near-Earth magnetotail provides here better conditions for magnetic reconnection. More stretched magnetotail is associated with stronger cross-tail plasma sheet current. In turn, this increases the probability to exceed the threshold of a current instability, which can, in particular, trigger the reconnection process. Recently, Nagai et al. (2005), on the basis of the Geotail spacecraft observations, concluded that during the solar maximum the reconnection process develops in the plasma sheet closer to the Earth than during solar minimum. The result in Fig 2 gives a clear explanation of this experimental fact.

Miyashita et al. (2004) found that, in average, reconnection occurred closer to the Earth produces stronger substorm (perhaps, this is due to the higher current density here). Thus, the magnetotail stretching should correlate with geomagnetic activity. Indeed, this holds true (e.g, Sergeev and Gvozdevsky, 1995). In this respect, the seasonal dependence of the stretching (Fig. 4) agrees with the equinoctial increase of the geomagnetic activity.

In addition, we would like to stress another possible application of the isotropy boundary investigations. Because of its nature, the isotropy boundary (as well as b2i) is the boundary demarcating the isotropic and anisotropic particle flux distributions in the magnetosphere. The anisotropic distribution of energetic protons provides the free energy for generation of EMIC waves. There is a growing interest to EMIC wave related scattering as one of main mechanisms of the ring current losses (e.g., Bespalov et al., 1994; Jordanova et al., 2001; Khazanov et al., 2002). Future models, that are to describe the losses more accurately, should take into account the location of the EMIC wave source. The IB (b2i) represents the high-latitude limit for the source location, and it is important to establish the dependence of this limit on different conditions including the solar cycle phase, interplanetary parameters, and geomagnetic indices. Some efforts have been undertaken in this direction on the basis of limited data sets (e.g. Lvova et al., 2005). More comprehensive study using the whole b2i data set available will be presented elsewhere.

Acknowledgements. This study is performed as a part of the basic research program №30 of the Presidium of RAS "Solar Activity and Physical Processes in the Sun-Earth system". The study was also supported by the Russian Basic Research Foundation (grants 03-05-20003 and 05-05-64214-a).

References

Jordanova, V. K., C. J. Farrugia, R. M. Thorne, G. V. Khazanov, G. D. Reeves, M. F. Thomsen. Modeling ring current proton precipitation by electromagnetic ion cyclotron waves during the May 14 - 16, 1997, storm, J. Geophys. Res., 106(A1), 7-22, 10.1029/2000JA002008, 2001.

Khazanov G. V., K. V. Gamayunov, V. K. Jordanova, and E. N. Krivorutsky. A self-consistent model of interacting ring current ions and electromagnetic ion cyclotron waves, initial results: Waves and precipitating fluxes, J. Geophys. Res., 107 (A6), doi:10.1029/2001JA000180, 2002.

Lvova E.A., V.A. Sergeev, G.R. Bagautdinova. Statistical study of the proton isotropy boundary. Ann. Geophys., V.23, 1311-1316, 2005.

Miyashita, Y., Y. Kamide, S. Machida, L. Liou, T. Mukai, Y. Saito, A. Ieda, C.-I. Meng, and G. K. Parks (2004). Difference in magnetotail variations between intense and weak substorms, J. Geophys. Res., 109, A11205, doi:10.1029/2004JA010588.

Nagai, T., M. Fujimoto, R. Nakamura, W. Baumjohann, A. Ieda, I. Shinohara, S. Machida, Y. Saito, and T. Mukai . Solar wind control of the radial distance of the magnetic reconnection site in the magnetotail, J. Geophys. Res., 110, A09208, doi:10.1029/2005JA011207, 2005.

Newell P.T., V. A. Sergeev, G. R. Bikkuzina, S. Wing. Characterizing the state of the magnetosphere: testing the ion precipitation maxima latitude (b2i) and the ion isotropy boundary. J. Geophys. Res., V.103, 4739-4745, 1998.

Newell P.T., Y.I. Feldstein, Yu. I. Galperin, C.-I. Meng, The morphology of nightside precipitation. J. Geophys. Res., V.101, 10737-10748, 1996.

Russell, C. T., and R. L. McPherron. The magnetotail and sub-storms, Space Sci. Rev., 15, 205–266, 1973.

Sergeev V. A., B. B. Gvozdevsky. MT-index - a possible new index to characterise the magnetic configuration of magnetotail. Ann. Geophys., V.13, 1093-1103, 1995.

Sergeev V. A., Sazhina E.M., Tsiganenko N.A., Lunbland J.A., Soraas F. Pitch angle scattering of energetic protons in the magnetotail current sheet as the dominant source of their isotropic precipitation into the nightside ionosphere. Planet Space Sci., 31, 1147-1158, 1983.